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# UTILIZING PHOTOVOLTAICS TO SUPPORT DISTANCE EDUCATION IN THE STATE OF CHIHUAHUA, MEXICO

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## ABSTRACT

The Chihuahua Distance Education Coordinating Committee (CEED) of the Mexican Secretariat of Public Education (SEP) implemented 54 photovoltaic (PV) systems for rural schools in 2002. Winrock International and New Mexico State University (NMSU) working under the U.S. Department of Energy (DOE) U.S. Agency for International Development (USAID) Mexico Renewable Energy Program (MREP) managed by Sandia National Labs, assisted with the project. Assistance included development of technical specifications, bid review, system design, training, and acceptance testing to help ensure high quality, safe, and reliable PV system implementation.

## 1.0 MEXICO DISTANCE EDUCATION

Distance education is a widely applied model used in schools throughout Mexico. Its objective is to provide middle school education to youngsters that live in rural and indigenous communities where access to modern education tools is limited. The Mexican distance education program uses

1.- Short 16 minute televised lessons that are transmitted from Mexico City via the satellite education program (EDUSAT') signal. Each satellite middle school (telesecundaria) is equipped with a parabolic dish to receive the signal and a television;

2.- Textbooks support the satellite lessons; and,

3.-The teacher than expounds on the transmitted satellite session using the textbook for another 32 minutes for a total session of 48 minutes.

This process is then repeated the next hour for the next class subject. For each grade, seven televised sessions are transmitted (7x16 min=112 min), thus the television will be used for a total of about 2 hours each day. Due to the 1 hour time difference between Chihuahua and Mexico City, broadcast transmissions begin early at 7:00 am , thus in the winter it is also necessary to have lights for the school during this early morning hour while it is still dark outside.

Fig. 1. Students benefiting from PV electrification at Chihuahua rural school.

Thousands of rural schools in Mexico do not have grid power. Some Mexican off-grid schools have used diesel or gasoline powered generators to meet their energy needs. However, the fossil fueled generators require frequent maintenance, are loud and disrupt teaching, as well as spewing out noxious fumes. Thus, some Mexican schools are adoting alternative technologies such as solar power. However, many early Mexican PV school systems were poorly designed and installed. They often failed and gave the technology a poor image. Many

Mexican off-grid schools have used diesel of gasoline powered generators to meet their energy needs. For instance, in 2001 the State of Queretaro deliberately opted out of using PV for two dozen schools and decided to use diesel generators instead due to distrust of PV technology. NMSU and Winrock are working through MREP to help change that negative image of PV and show Mexican educational administrators that PV can indeed play a valuable role with providing electricity to rural schools. Chihuahua has now led the way in Mexico in using quality PV systems to meet rural school energy needs.

The power needs for a typical telesecundaria in Chihuahua are as follows:

- 1 to 2 - color TVs, 175 W, 2 hrs/day
- 2 to 4 - fluorescent lamps, 20 W, 1 hr/day
- 1 - VCR, 25 W, 2 hrs/day

## 2. MREP SUPPORT TO CHIHUAHUA

For the Chihuahua rural schools electrification program, SEP in the State of Chihuahua utilized PV power systems to meet energy needs for their rural secondary schools which provide satellite based distance education programs. In Chihuahua, the program led to the installation of PV systems for 54 rural Chihuahua telsecundarias schools during September-November 2002. This project has now gained the interest of severn other Mexican SEP offices and is paving the way for additional PV schools in Mexico. Winrock and NMSU supported the Chihuahua project as follows:

### 2.1 Determining School Power Needs

Schools had to be evaluated as to their power requirements for budget estimation purposes. Schools basically fell into two category sizes depending on number of classrooms and number of televisions needed. The power needs for a typical telesecundaria in Chihuahua were determined and two PV system sizes were finalized, one utilizing a 550 Wp PV array, and the other with a 300 Wp PV array

### 2.2 Mimimum Technical Specification

SEP has previously used PV technology in Chihuahua and elsewhere but often with poor results due to poorly designed PV systems. For this project, NMSU assisted SEP in developing a minimum technical specification that meets the Mexican electric code for PV installations. This helps ensure system quality and code compliance.

### 2.3 Bid Review and Recommendations

As a public institution, SEP must follow strict Mexican bidding rules. Winrock and NMSU assisted SEP throughout this process by meeting with potential suppliers to educate them on the technical specification, reviewing vendor bids, and making recommendations to SEP on submitted bids.

Fig. 2. Yepachi telesecundaria and PV system in western Chihuahua.

### 2.4 Design Review

After the bid was awarded, NMSU worked closely with the Mexican vendor (SIMOSOL) to help refine the PV system design to be sure that it meets Mexican PV code regulations. The PV systems were designed to meet the needs for small and large size telesecundarias. Systerms were sized to provide 3 days autonomy under normal use in sunny Chihuahua (about 4 kWh/m$^2$/day winter average). Array tilt was optimized for winter usage since school is out in the summer.

The PV system utilized appropriate overcurrent protection. All metal enclosures and frames were bonded and the negative grounded. The battery bank was placed in an enclosure inaccessible to students. All interior wire runs were placed in conduit. All of these details help ensure a safe and quality PV installation. Total PV system hardware for the 54 schools was installed for US$250,000 paid by CEED Chihuahua, thus installing a total of 20 kW PV.

There were also additional costs to State of Chihuahua project administration and implementation, as well as additional in-kind support from MREP.

## 2.5 Technician Training

Training is an integral part of sustainable development for any PV program. MREP assisted SEP with training of 54 teachers on operation and maintenance of the school PV systems. In addition, a more in-depth technical training was held for 27 EDUSAT technicians from Chihuahua and seven other northern Mexican states that are interested in replicating the Chihuahua PV telesecundarias model established with this project.

Fig. 3. Training of 27 EDUSAT technicians from 7 states by NMSU and SIMOSOL at Chorreras PV telesecundaria.

## 2.6 Support Materials

NMSU developed a training manual for EDUSAT technicians. NMSU and Winrock also developed a handbook for users, who in this case are teachers and the rural communities. The handbook contains basic information about PV technology, operation, and maintenance for school projects.

## 2.7 Acceptance Testing

Acceptance testing of installed PV systems is an important part of any large scale program utilizing the technology. This is necessary to verify that technical specifications were fulfilled and properly installed and meet NEC standards. In November 2002, NMSU assisted SEP with this testing at six schools, while SEP continued testing on their own afterwards at the remaining schools. Acceptance testing conducted on the Chihuahua telesecundaria PV systems verified that they were installed properly and as designed. Except for a failed charge controller in one system, the PV systems worked well and had been sized adequately to meet the telesecundarias power needs during the winter. The most important point of this exercise in the field was to teach EDUSAT field technicians from Chihuahua how to adequately assess the quality and operation of installed PV systems.

Fig. 4. NMSU engineer Luis Estrada conducting school teaching PV system acceptance testing techniques for EDUSAT.

## 2.8 Long Term Evaluation

These systems will continue to be moniotered by NMSU on a long term basis to verify performance and help improve future system design.

## 3.0 PV SYSTEM DESIGN

The PV systems were designed to meet the needs for small and large size telesecundarias. Systems were sized to provide 3 days autonomy under normal use in sunny Chihuahua (about 4 kWh/m$^2$/day winter average). Total PV system hardware for the 54 schools was installed for US$250,000 utilizing a total of 20 kW PV. PV system sizes used were 550 Wp PV and 300 Wp PV array for large and small rural schools. The Chihuahua Secretariat of Education installed 54 PV systems for rural elementary schools throughout 15 counties in Chihuahua. The PV systems were designed to allow the school to have access to national satellite course modules, as well as lighting for classrooms. A general system schematic is shown in Figure 5 for a larger type system.

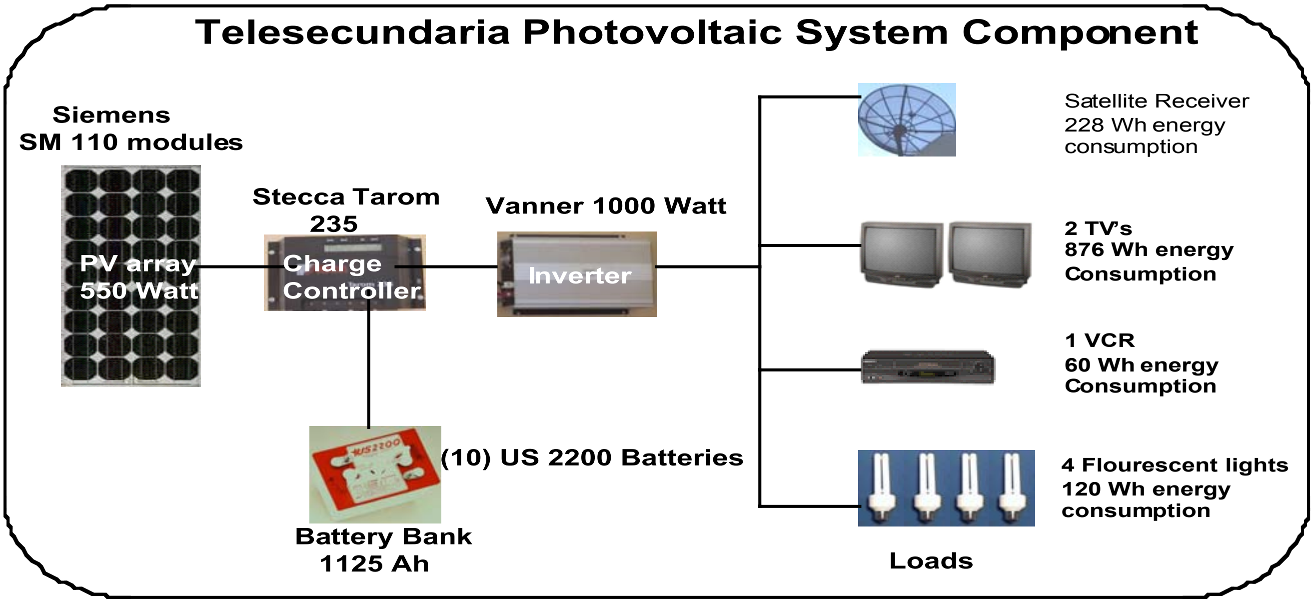


Fig. 5. Block diagram of Chihuahua PV telesecundaria system (Larger 550 Wp System)

3.1 Photovoltaic array

The PV array is comprised of Siemens modules installed at local latitude plus 15° (typically about 45°) tilt supported on a galvanized steel structure. The array mounting structure is held vertically on a 6 m high, 4 inch diameter galvanized steel pole that is capable of withstanding strong winds (>160 kph). In addition the high pole reduces the chance of module damage from curious children, as well as reducing theft. All nuts and bolts used were stainless steel. All PV modules were inappropriately bonded originally using a daisy chain that NMSU had the vendor more appropriately correct to a single bond across all module frames. Each module bond used a star washer for better contact to the aluminum module frame. The PV array is properly sized for meeting the energy requirements of the schools, either 300 or 550 Wp. Anything smaller would be inadequate for these rural schools and would not provide sufficient energy to meet the power needs.

3.2 Charge Controller

The charge controller used for the more commonly installed smaller systems is a solid state ProStar 30 with a maximum listed rating of 30 amps. For the larger systems a solid state Stecca tarom charge controller was used. These UL listed controllers are correctly sized to handle the maximum short circuit current that can be produced by the PV array (>1.56 Isc). There is a LVD and HVD function as specified by the NMSU technical specification for EDUSAT to protect from overcharging or excessively deep discharging the battery bank.

Fig. 6. Controller, inverter, disconnects.

3.3 Inverter

The Inverter is a Vanner PCS12-121K with a nominal voltage input of 12V. The rated continuous power is 1000 W with a surge rating of 2100 W.

3.4 Overcurrent Devices

A UL listed dc rated disconnect was installed appropriately near the batteries utilizing a NEC required chassis ground. The PV array likewise utilized an individual dc listed disconnect.

3.5 Batteries

The batteries utilized in the systems are US2200 lead-acid deep-cycle batteries. They were enclosed in a metal containment box with a side grating to allow for good ventilation. Each battery has a capacity of 225 Ah and the battery bank was adequately sized for the rigorous use expected of them and should provide 5-6 years of service (325 Ah for the small systems and 1125 Ah for the large systems).. These batteries require periodic maintenance through the addition of distilled water to maintain good battery life. The local schoolteachers were trained by NMSU and EDUSAT on how to properly maintain adequate battery water levels. Although metal enclosures for batteries are acceptable, plastic boxes are more ideal as they will not suffer any corrosion in case of battery acid leakage. Importantly, access to the battery bank is restricted to students via a heavy duty lock installed on the battery bank box.

Fig. 7. Jorge Colmenero of EDUSAT evaluating school battery bank during acceptance testing.

**4**.0 PROJECT RESULTS

The 54 PV systems were used for the first time during the winter of 2002-03. The teachers were quite satisfied with the systems and their performance during this first year and no problems were reported and everyone reported sufficient power.

NMSU accompanied EDUSAT as part of training activities to conduct acceptance tests on six installed systems in November, 2002. The acceptance tests were conducted on randomly selected installed systems and were used to verify operational status and whether the installation met the technical specifications set forth by NMSU for EDUSAT for these projects. The vendor (SIMOSOL) also accompanied the team for these inspections. The continued field training enabled EDUSAT technicians to become adequately versed for conducting their own acceptance test on the remaining 48 PV installations. The following is a list of the initial telesecundarias PV systems visited by NMSU and EDUSAT:

- Escuela Telesecundaria de Yapachi:
Installation Type: 300 Wp
Municipality: Temosachi
- Escuela Telesecundaria de Huevachi:
Installation Type: 300 Wp
Municipality: Ocampo:
- Escuela Telesecundaria de Bermudez:
Installation Type: 300 Wp
Municipality: Moris
- Escuela Telesecundaria de El Pilar:
Installation Type: 550 Wp
Municipality: Moris
- Escuela Telesecundaria de Ocampo:
Installation Type: 550 Wp
Municipality: Ocampo
- Escuela Telesecundaria de Chorreras
Installation Type 300 Wp
Municipality: Aldama

Fig. 8. Bermudez telesecundaria with new EDUSAT PV system.

Fig. 9. Ocampo PV powered telesecundaria and satellite dish.

The evaluation conducted on the Chihuahua telesecundaria PV systems verified that they were installed correctly and met the system technical specifications. There were only a few minor technical details that the vendor was asked to correct. The PV systems worked well and had been sized adequately to meet the telesecundarias power needs during the winter. The systems evaluated showed good workmanship and functioned as designed. Only the PV system in Ocampo was initially not working properly due to a defective ProStar controller that was soon replaced.

Minor changes that were made to the final installations included:

- PV array bonding was upgraded to a continuous grounding conductor between all module frames instead of using individual terminal connector at each module frame (i.e., no daisy chaining);

- Anti-corrosive spray protection was added to battery terminals to reduce any future potential corrosion;

- The PV array tilt was increased from ~30° by an additional 15 degrees (to ~45°) to better take advantage of winter insolation (as schools are not used in the summer). This will allow for maximum energy production during the critical winter period.

As set forth in the NMSU/EDUSAT in the original technical specification, SIMOSOL will conduct two periodic checkups during the first two years of operation. This inspections will be useful to detect any potential late developing problems such as corrosion, loose connections due to thermal stress, faulty components, etc. It will also help serve as a reminder to the school teachers to periodically water the battery bank.

## 5.0 CONCLUSIONS

The electrification of 54 telesecundaria schools in Chihuahua with PV was successfully complete in November, 2002. The DOE/USAID Mexico Renewable Energy Program provided key support for this project that gained the confidence of Mexican decision-makers to use PV technology. This was not a simple decision in that a few schools had already previously used PV with little success in Mexico due to poorly designed and installed PV systems that never functioned properly. The MREP program provided the technical know-how and experience to the State of Chihuahua to avoid repeating these errors from the past and showing that PV was indeed a viable solution. This new program in Chihuahua is paving the way for quality PV installations that are code compliant and gaining the confidence of school planners across Mexico.

## 6.0 REFERENCES

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